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Development of Carbon Dioxide Removal System from the Flue Gas of Coal Fired Power Plant

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Abstract

A quarter of the carbon dioxide emissions all over the world are exhausted from the thermal power plants. So we have been concentrated on the development of the low–cost CO_2 capture technology. For the CO_2 capture from the large amount of the flue gas, the chemical absorption method is suitable. We found an amine solvent had a good performance using thermodynamic simulation. The solvent exhibited that the CO_2 recovery ratio and heat consumption for CO_2 regeneration were 94% and 2.9GJ/t-CO_2 by the bench-scale test, respectively. Furthermore we will plan a 10 ton-CO_2/day pilot plant using a real coal combustion gas.

Post combustion; CO_2 capture; amine; regeneration energy

1. Introduction

Over the past decade, the global warming resulting from anthropogenic carbon dioxide (CO_2) has become one of the most important environmental matters. A quarter of the CO_2 emissions all over the world are exhausted from the thermal plants. Post-combustion carbon dioxide capture is the technique that can be rapidly and safely employed for substantially reducing carbon dioxide emissions from existing and near future power plants.

In this paper, we evaluated thermodynamically both single and mixed amine-based absorbents in terms of energy consumption for carbon dioxide (CO_2) desorption. We selected one amine-based aqueous solution (Toshiba solvent 1, TS-1) and have been evaluating the energy consumption for CO2 desorption using bench-scale test facility.

2. Toshiba's R&D approach

Toshiba has focused the development of the post combustion CO_2 capture process from flue gas of coal fired power plants. The reasons are the follows;

1. Post combustion CO_2 capture system can be applied to not only new plants but also for retrofit plants.

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2. Application of CCS for coal fired power plants produces the highest reduction in CO_2 emission because coal has the highest carbon content in the all fossil fuel.
3. Coal will continue to be an important, cheap and convenient fuel for future power generation as long as the environmental issues can be solved.

Our R&D approach for CO_2 capture technology is shown in Table 1.

TABLE 1
TOSHIBA'S R&D APPROATCH FOR CO_2 CAPTURE TECHNOLOGY

Study 1 "Development of Solvent"
- Screening of solvent by thermodynamic process simulation
- Evaluation and optimization of solvent performance by lab-scale experiments
Study 2 "Design tuning of CO_2 capture process to identify the best solvent performance."
- Development or study of process elements by experiments
- Evaluation and optimization of process performance by bench-scale test and pilot plant test
- Design of full-scale equipments of CO_2 capture process
Study 3 " Power plant design with CO_2 capture"
- Design optimization of power plant with CO2 capture process
- Study for CCS ready plant

3. Screening of solvent by thermodynamic process simulation

Figure 1 shows the CO_2 absorption/desorption cycle, which includes an absorber, a stripper, and a lean/rich heat exchanger.

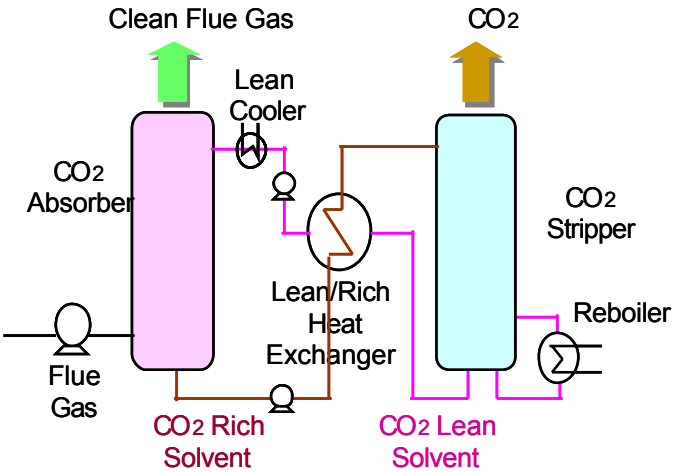

Figure 1: Outline of CO_2 absorption/desorption cycle

We simulated thermodynamically this cycle using the chemical process simulator which is combined with the special thermodynamic database concerning amine solutions. We estimated the consumed heat in the stripper when the flue gas contains 12 volume % CO_2 and the removal of carbon dioxide from the flue gas is 90%. We optimized the operating parameters of the CO_2 absorption/desorption cycle for amine solutions, respectively.

Figure 2 shows the results of thermodynamic simulation on the lowest heats consumed in the stripper for three amine solutions. The lowest heat consumed in the distiller for the general 30 weight % mono-ethanolamine (MEA) aqueous solution is 4.4GJ/t-CO_2, which is nearly equal to the literature value [1]. The value for the aqueous 2-amino-2-methyl-l-propanol (AMP) solution is about 15% less than that of MEA solution. Furthermore, the value for TS-1 is about 37% less than that of MEA solution.

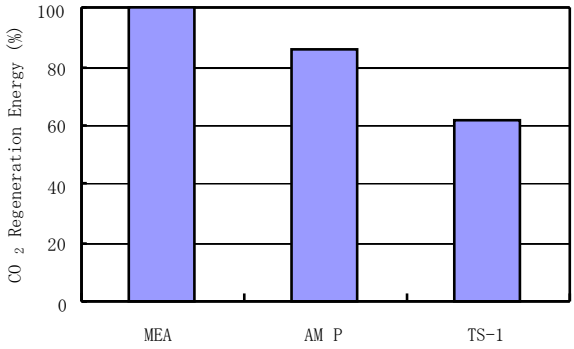

Figure2: CO_2 regeneration energy resulted from thermodynamic simulation

4. Bench-scale test

After the absorbent evaluation using the thermodynamic absorption/desorption cycle simulation is completed, the operation of the absorption/desorption process was tested for the most promising solvent, TS-1. The test plant with a complete absorption/desorption process has the absorber with the diameter of 160mm and the height of 6,000mm, and the stropper with the diameter of 200mm and the height of 3,600mm, whose photo is shown in fig.3. A flue gas of coal-fired power plant was simulated by a mixture of air and carbon dioxide whose volume ratio is 88:12. We optimized the simulated flue gas space velocity and the weight ratio of the absorbent to the simulated flue gas in the absorber.

In the bench-scale test, TS-1 solvent exhibited that the CO_2 recovery ratio and heat consumption for CO_2 regeneration were 94% and 2.9GJ/t-CO_2, respectively.

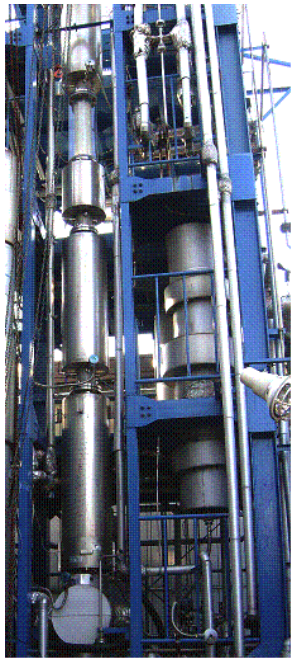

Figure3: A photo of bench-scale test facility

5. Plan of pilot plant

We plan the pilot plant (10ton-CO_2/day) which will start in 2009 using the actual flue gas from a coal fired boiler in Japan. Table 2 shows the design summary of the pilot plant combined with a coal-fired power plant.

TABLE 2
PILOT PLANT DESIGN SUMMARY

Site:	Domestic sm all coal fired power plant
Supplied gas:	Flue gas from the coal fired boiler
Capacity:	2000Nm^3/h for flue gas
	10t-CO_2/day at 90% of CO_2 capture ratio
Absorber:	
	Diameter ~1m
	Height ~21m
Stripper:	
	Diameter ~0.8m
	Height ~12m

6. Conclusions

For post combustion CO_2 capture, we have selected TS-1 solvent from the aqueous amine solutions using the thermodynamic absorption/desorption cycle simulation. In the bench-scale test, TS-1 solvent exhibited that the CO_2 recovery ratio and heat consumption for CO_2 regeneration were 94% and 2.9GJ/t-CO_2, respectively. We will evaluate TS-1 solvent using the pilot plant (10ton-CO_2/day class) which will start in 2009 using the actual flue gas from a coal fired boiler in Japan.

REFERENCE

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